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Cumulative assessment: Does it improve students' knowledge acquisition and retention?

Avaliação cumulativa: melhora a aquisição e a retenção do conhecimento pelos estudantes?

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ABSTRACT

AIMS: Cumulative assessment has been used as a tool to steer students' study behavior, since it increases students' self-study time while spreading their study time more evenly throughout the span of the course. However, little is known about the impact of cumulative assessment on students' knowledge growth. Therefore, our study compared the growth of knowledge of students who attended a course with cumulative assessment with those with end-of-course assessment. We hypothesized that students in the cumulative assessment condition would have a higher increase in knowledge compared to students in the end-of-course assessment condition.

METHODS: This is a follow-up study of a previous randomized experiment that compared students' performance between students who attended a course with cumulative assessment with those with end-of-course assessment. We gathered data of the first four subsequent Dutch interuniversity progress test after the experiment from 62 students. Of those, 37 students were in the end-of-course assessment condition and 25 were in the cumulative assessment condition. The questions were classified as part of the teaching block or not. To analyze students' knowledge growth, we conducted a General Linear Model.

RESULTS: Our results demonstrated that there was a significant increase in students' knowledge of the four subsequent progress tests. Additionally, our general linear model showed no difference between both groups, indicating that cumulative assessment and end-of-course assessment produced similar outcomes when comparing students' knowledge growth.

CONCLUSIONS: So far, little evidence has supported the use of cumulative assessment as a tool for increasing students' knowledge growth. The lack of finding a positive effect of cumulative assessment on knowledge retention may be explained by the repetitive character of our (spiral) curriculum.

KEYWORDS: educational assessment; Progress Testing; Undergraduate medical training; medical education.

RESUMO

OBJETIVOS: A avaliação cumulativa tem sido usada como uma ferramenta para orientar o comportamento de estudo dos alunos, uma vez que aumenta o tempo de auto aprendizado, ao mesmo tempo que distribui o tempo de estudo de forma mais uniforme ao longo do curso. No entanto, pouco se sabe sobre o impacto da avaliação cumulativa na evolução do conhecimento dos estudantes. Portanto, nosso estudo comparou o aumento do conhecimento entre estudantes que participaram de um curso com avaliação cumulativa, e aqueles que tiveram avaliação de fim de curso. Nossa hipótese é que os estudantes na condição de avaliação cumulativa teriam um aumento maior no conhecimento em comparação com os estudantes na condição de avaliação do final do curso.

MÉTODOS: Este é um estudo de acompanhamento de um experimento randomizado anterior, que comparou o desempenho entre estudantes que participaram de um curso com avaliação cumulativa e aqueles com avaliação de fim de curso. Nós reunimos dados dos primeiros quatro Testes do Progresso interuniversitários holandeses subsequentes ao experimento, em 62 estudantes. Destes, 37 estavam na condição de avaliação de final de curso e 25 estavam na condição de avaliação cumulativa. As questões foram classificadas como parte do bloco de ensino ou não. Para analisar o crescimento do conhecimento dos estudantes, conduzimos um Modelo Linear Geral.

RESULTADOS: Nossos resultados demonstraram que houve um aumento significativo no conhecimento dos estudantes nos quatro Testes do Progresso subsequentes. Além disso, nosso modelo linear geral não mostrou diferença entre os dois grupos, indicando que a avaliação cumulativa e a avaliação no final do curso produziram resultados semelhantes ao comparar o crescimento do conhecimento dos alunos.

CONCLUSÕES: Até agora, pouca evidência apoiou o uso da avaliação cumulativa como uma ferramenta para aumentar o crescimento do conhecimento dos alunos. A falta em encontrar um efeito positivo da avaliação cumulativa na retenção de conhecimento pode ser explicada pelo caráter repetitivo do nosso currículo (em espiral).

DESCRIPTORIOS: avaliação educacional; Teste do Progresso; educação de graduação em medicina; educação médica.

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Abbreviations: GLM, General Linear Model; PBL, Problem Based Learning.

INTRODUCTION

The very existence of schools and universities rests on the assumption that people acquire and retain knowledge in order to reproduce it in the future [1]. Acquiring and retaining knowledge is generally considered complete when a student can produce the correct answer to a test question. Throughout history, knowledge acquisition and retention has been investigated by letting people study the material over a certain period of time [2] and then testing what has actually been learned.

Dunlosky et al. [3] have revised the literature regarding different studying strategies that may impact learning. Interestingly, they demonstrated that testing is the most effective studying technique, followed by spacing the study sessions [3]. Although reinforcement of learning, i.e. when the material is repeated over time, is proved to improve knowledge retention [2,4-7], research has shown that medical students may forget around 50% of the learned material over time (for a review see Custer [8]).

Spacing the study material is part of reinforcement of learning. Studying material over two or more sessions leads to higher retention compared with studying the same material in a single session [9,10]. This is known as the spacing effect [11-13]. The spacing effect has been extensively investigated in cognitive psychology (for a review see Carpenter et al. [9]). The spacing effect also has been studied in medical education [14-17]. Studies suggest that spacing the study material increases retention in a proportional way [18,19]. Usually, the inter-study interval, the gap between sessions, should be between 10% and 20% of the retention interval, which is the gap between the last session and the retention test.

Although re-studying the material has been shown to improve retention, research has also shown that testing improves retention more than re-studying (for a review see Delaney et al. [20]). This is referred to as the testing effect [21-23]. Testing has been used as a high utility learning technique [3,23,24] to enhance both learning and retention [2,3,25]. Testing can be used as both an assessment and a learning tool, since it improves knowledge retention compared to re-studying the material [6]. Furthermore, repetitive testing promotes better retention compared to a single

test, which, in turn, has better retention compared to no testing [23]. Repetitive testing strategies can also stimulate repeated learning as it enhances the number of study hours [26]. Therefore, repetitive testing seems to be more suitable as learning tool than solely end-of-course assessments [6].

Testing may also increase the amount of feedback. Feedback in education is an important tool to monitor progress and improve academic achievement. The delivery of feedback on a test promotes recapitulation of the material that was not fully comprehended before [27]. Although there is not a clear indication of when this feedback should be given (delay vs. immediate feedback), research has shown that giving feedback on tests improves retention more than a lack of feedback [28].

Spacing and testing effects can be used independently to improve retention, but their effectiveness increases when they are combined [29]. Adding a test into the learning sequence increases the likelihood that the learner remembers the material during a subsequent test [30]. A recent review by Day et al. [31] demonstrated that repetitive testing is widely used in higher education. Although the tests' characteristics varied extensively across studies, repetitive testing may improve students' grades. Adding extra tests as a learning tool may improve retention more than merely studying the material.

Cumulative assessment is a method that combines repetitive testing, repetition of content, compensation across tests, and feedback between tests, in order to stimulate students to study [26]. Repetitive testing is considered a strong external stimulus to study behavior, because students are forced to start studying early in the course. Additionally, students who followed a course with cumulative assessment spent more hours on self-study and their efforts were spread more evenly over the time span of the course [32]. Surprisingly, it has not yet been proved whether cumulative assessment has any influence on students' knowledge growth. In this study we compared knowledge growth of students who attended a course with either end-of-course or cumulative assessment.

Our study builds on knowledge from a previous experimental study comparing the effects of end-of-course and cumulative assessment on students' study behavior and knowledge acquisition [26,32]. To understand the effect of both assessment conditions on students' knowledge growth over time, we performed a follow-up study of students' knowledge growth within one year. We hypothesized that students who are assessed in a cumulative way will gain more

knowledge than students who are solely tested using end-of-course assessment.

METHODS

Participants and setting

The current study was performed using the progress test data of 62 second-year medical students (22 males and 40 females) who voluntarily participated in an experiment on cumulative assessment at the University of Groningen in the Netherlands. Of the 62 students, 37 were in the end-of-course assessment condition and 25 were in the cumulative assessment condition. For more details about the sample and methodology, please see Kerdijk et al. [26]. Prior to the experiment, the groups did not differ in GPA (grade point average). All students had previous experience with both cumulative assessment and end-of-course assessment. Failing the regular assessment would result in a one-year delay, so the stakes for passing the exam were high. Ethical approval for the experiment was obtained from the Ethical Review Board of the Netherlands Association for Medical Education (NVMO-ERB) and the institutional Board of Examiners. For the current study, no new ethical approval was sought, because reanalysis of historical data is exempt. Following the Declaration of Helsinki and the privacy policy of the University of Groningen, all data were anonymized and handled with confidentiality.

Procedure

The previous study [26] was performed in a 10-week course. In the cumulative assessment condition, three multiple-choice tests were administered at the end of weeks four, eight, and ten. Each test covered the study contents of all previous weeks. Since the subsequent tests had more content to be covered, the number of items per test increased. For each test, feedback was provided through the university digital learning environment. Students in the end-of-course assessment condition sat one multiple-choice test at the end of week 10. End-of-course and cumulative assessment (combination of three tests) both consisted of the same number of questions ($n=95$). Of these 95 questions, 48 questions were the same in both assessments, because those questions were included in the final test for the cumulative assessment condition. For more information please see Kerdijk et al. [26].

In addition to the block examinations (end-of-course or cumulative assessment), students have to take the Dutch progress test. The content of the Progress Test is

based on the Dutch National Blueprint for the Medical Curriculum with regard to the knowledge objectives of undergraduate medical schools at graduation [33]. Students have to sit the progress test four times a year at fixed intervals. Each progress test contains 200 multiple-choice questions and is constructed to reflect the entire domain of medical knowledge (for more information see Tio et al. [33]). Students are allowed to not answer a question by filling an 'I don't know' option. A correct answer is coupled with one point, an incorrect answer with a penalty and when students fill in the 'I don't know' option, they receive neither one point nor a penalty.

For our study, we gathered data of four subsequent Dutch interuniversity progress tests from all of the 62 medical students as a follow-up measure of the experiment.

Data Analysis

First, the items of four subsequent Progress Tests were categorized as belonging or not to the 10-week course by one of the authors (RT). As the number of questions varied between both tests, we calculated percentages for the questions. Subsequently, we tested the assumptions of homogeneity for the different test moments using Levene's Test of Equality of Error Variances and Box's test of Equality of Covariance Matrices. Then, we compared the scores of the students over time using a General Linear Model (GLM). In GLM, students' score was set as a dependent variable, group was set as a fixed factor and time was set as a random factor.

RESULTS

Looking at Levene's Test of Equality of Error Variances, the assumption of homogeneity variance is met for the different test moments. Box's test of Equality of Covariance Matrices shows that the assumption of the covariance matrices being equal is met for the four subsequent progress tests. Therefore, we continued with the analysis.

The results of the GLM showed a main effect for time ($F(3, 3)=1020.286$, $p<0.001$). However, there was no main effect for groups ($F(1, 1)=1,861$, $p>0.05$), indicating that there was no difference between groups. Additionally, the interaction effect between time and group (cumulative and end-of-course assessment) was not significant, ($F(3, 225)=0.041$, $p>0.05$). This means that the null-hypothesis was not violated; cumulative assessment had no significant effect on knowledge growth when compared to end-of-course assessment. Students' knowledge growth is displayed in **Figure 1**.

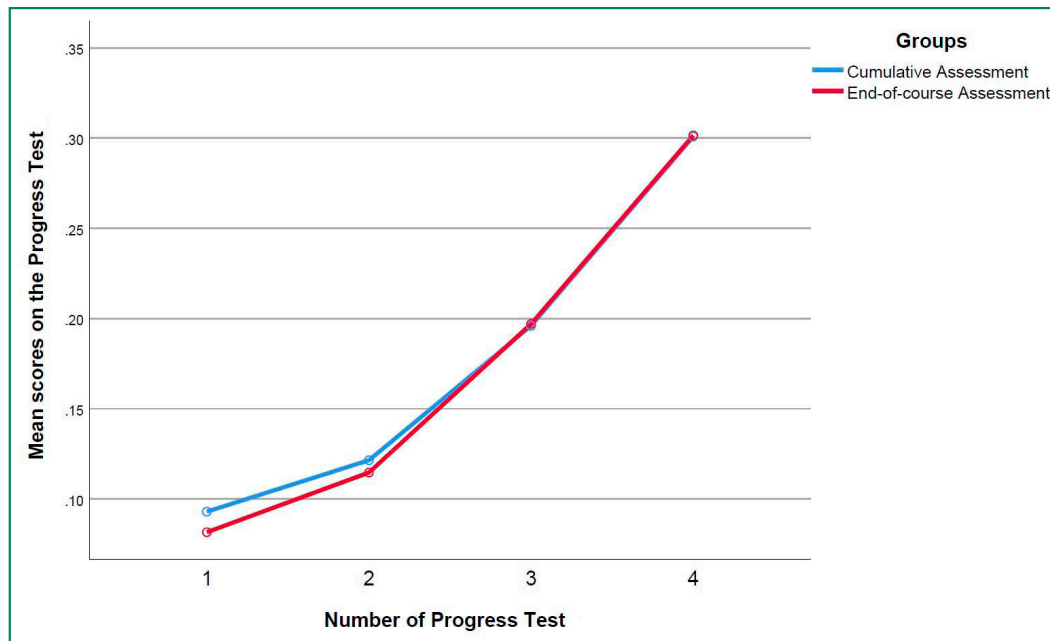


Figure 1. Growth of scores on questions belonging to the ten-week course in four consecutive Progress Tests (1 month, 5 months, 8 months and 11 months after the course) of 62 students, 25 students in the cumulative assessment condition, and 37 students in the end-of-course assessment condition.

DISCUSSION

The purpose of this research was to compare knowledge growth of students who attended a course with either cumulative assessment or end-of-course assessment. We hypothesized that cumulative assessment would improve students' knowledge growth over time compared to end-of-course assessment. Our results showed that students in both groups significantly acquired and retained more knowledge over time, but there was no difference between both groups, so our hypothesis was not confirmed. Assessment for learning means changing students' behavior regarding their learning [34]. Although cumulative assessment has been shown to increase students' self-study time and spread their study time throughout a course [32], previous studies revealed no difference in students' knowledge at the end of the course, with the exception of the content of the last part of the block [26].

Repetitive testing improves retention and allows for more feedback opportunities when compared to end-of-course assessment. The delivery of feedback reinforces studying material that was not fully comprehended before [22,27]. It is assumed that learning occurs while studying the material and that longer periods of studying should increase learning and, therefore, retention. The results of our study,

however, do not support the hypothesis that students in a cumulative assessment condition have increased knowledge retention compared to students in an end-of-course assessment condition. Probably, this might be due to the comprehensive integrated teaching at our university, in which the study material is repeated over time [35,36] preventing knowledge to decay in the end-of-course assessment condition. Alternatively, the gap between the tests in the cumulative assessment condition may not be optimal to reflect differences in retention. Research on the spacing effect has shown that the gap between re-studying sessions is key to retention, meaning that there is a relation between the intervals and retention. Future research should investigate whether the gap between tests has an influence on students' knowledge retention.

The course on which this study is based was a Problem Based Learning (PBL) course. PBL programs stimulate studying on a weekly basis to be able to make a valuable contribution to the subsequent sessions. Usually, PBL requires more self-study time than traditional curricula (for an overview see Schmidt et al. [37]). Additionally, similar to cumulative assessment, PBL tutorials stimulate students to regularly retrieve and apply acquired knowledge throughout a course, which improves retention. This means that students in both conditions had assignments

on a weekly basis to meet weekly deadlines. This may have suppressed the effect of cumulative assessment on knowledge retention. It could therefore be argued to what extent the conditions differed sufficiently, since both groups had weekly assignments. Future research should therefore aim at comparing knowledge retention between different types of curricula, especially a curriculum in which the content is not repeated over time. Another limitation of our study refers to the fact that our measure of knowledge retention was based on one course, which may have been too limited to generalize our findings to other curricula or courses.

Although there was no difference on knowledge growth between students in cumulative assessment and end-of-course assessment conditions, their knowledge increased over time. So far, evidence that cumulative assessment benefits retention is lacking. Since our study was performed in a curriculum in which the material was repeated over time using different teaching methods, further research should verify in which type of curricula cumulative assessment benefits students' knowledge growth.

NOTES

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Conflicts of interest disclosure

The authors declare no competing interests relevant to the content of this study.

Authors' contributions

All the authors declare to have made substantial contributions to the conception, or design, or acquisition, or analysis, or interpretation of data; and drafting the work or revising it critically for important intellectual content; and to approve the version to be published.

Availability of data and responsibility for the results

All the authors declare to have had full access to the available data and they assume full responsibility for the integrity of these results.

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